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Extragalactic jets on subpc and large scales

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Abstract Jets can be probed in their innermost regions ($d \lesssim 0.1$ pc) through the study of the relativistically boosted emission of *blazars*. On the other extreme of spatial scales, the study of structure and dynamics of extragalactic relativistic jets received renewed impulse after the discovery, made by *Chandra*, of bright X-ray emission from regions at distances larger than hundreds of kpc from the central engine. At both scales it is thus possible to infer some of the basic parameters of the flow (speed, density, magnetic field intensity, power). After a brief review of the available observational evidence, I discuss how the comparison between the physical quantities independently derived at the two scales can be used to shed light on the global dynamics of the jet, from the innermost regions to the hundreds of kpc scale.

Keywords Galaxies: active — galaxies: jets — (galaxies:) quasars: X-rays: galaxies

1 Introduction

Despite decades of intense study, the physical mechanisms acting behind extragalactic relativistic jets are still poorly constrained (e.g. De Young 2002). One of the major difficulties derives from the fact that even the basic physical quantities characterizing the flow (speed, density, composition, geometry and intensity of magnetic fields) are still unaccessible to a direct measure. Classical studies in the radio band, probing a small portion of the synchrotron emission from relativistic electrons, are intrinsically limited and the physical parameters of the plasma can be evaluated only with several assumptions (e.g., equipartition between particles and magnetic fields, minimum energy of the emitting electrons). Multifrequency observations offer a good way to effectively overcome these difficulties, helping us to disentangle the basic physical quantities. In this respect, the best example is offered by the study of jets in blazars, for which the modeling of the emission based on the synchrotron and Inverse Compton mechanisms allows us to derive robust estimates of the main parameters of the inner flow. In recent years, the extension of the observations of large scale jets to the optical and the X-ray band (possible thanks to the spatial resolution of *Chandra*), have renewed the interest for the field. Particularly exciting is the possibility that the X-ray emission detected from jets in powerful quasars are produced by a mechanims different from the synchrotron one, offering the possibility to disentangle the basic physical parameters.

In the following I will discuss recent developments made in the study of blazars (focusing in particular on the determination of the jet power and the comparison with the accretion power) and in the multifrequency investigation of large scale jets of powerful quasars. Finally I will discuss how, comparing the physical properties independently derived in the same jet in the blazar region and at large scale, important clues on the global dynamics of the jet can be derived.

2 Blazars: probing the inner jet

Blazars are excellent laboratories to study the innermost region of jets. Their highly variable, relativistically boosted, non-thermal continuum is produced by high-energy electrons (or pairs) in a relativistic jet closely aligned with the line of sight (Blandford & Rees 1974). The small variability timescales, coupled with the condition that the source is transparent to γ-rays,

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allows one to constrain the distance of the emission region around 10^{17} cm from the central Black Hole (Ghisellini & Madau 1996), corresponding to $10^2 - 10^3$ gravitational radii for typical BH masses. In the widely discussed "internal shock" scenario (Ghisellini 1999, Spada et al. 2001) this distance marks the region where shells of matter ejected by the central engine with different velocities preferentially collide (but see Katarzynski & Ghisellini 2007), producing shocks at which the magnetic field is amplified and relativistic electrons responsible for the emission are accelerated. Alternatively, the blazar emission could trace the instabilities in the flow arising at the end of the acceleration region, where MHD processes accelerate the flow to relativistic speeds (Sikora et al. 2005).

2.1 Emission models - The "blazar sequence"

The Spectral Energy Distribution of blazars, covering all the electromagnetic spectrum, from radio frequencies up to GeV-TeV energies, is characterized by two broad bumps, the first peaking between the IR and the X-ray band, the second one in the gamma-ray domain. The first peak traces the synchrotron emission of relativistic electrons, while the high-energy component is presumably due to the Inverse Compton scattering between the same electron population and soft photons, both the synchrotron photons themselves (SSC mechanism; Maraschi, Ghisellini & Celotti 1992) and ambient radiation entering the jet (External Compton; Dermer & Schlickeiser 1993, Sikora, Begelman & Rees 1994), although other possibilities, possibly involving hadrons, cannot be ruled out (e.g., Mannheim 1993, Aharonian 2000, Mücke et al. 2003). In low power sources (generally lineless BL Lac objects) it is assumed that the IC component is dominated by the SSC process, while in powerful quasars (mostly Flat Spectrum Radio Quasars), characterized by the presence of bright emission lines, the EC process likely dominates. The simplest model ("one-zone") assumes that the bulk of the emission is produced within a single region.

As shown by Fossati et al. (1998), the position of the peaks in the SED is related to the luminosity of the emission (the so called "blazar sequence", see also Sambruna, these proceedings). Powerful sources have both peaks located at low frequencies (IR and MeV band). Moving from high to low luminosities, both peaks shift at larger frequencies reaching, in the low luminousity BL Lac objects, the X-ray band (synchrotron) and the TeV band (IC). A trend is also present in the relative importance of the synchrotron and IC peaks. The latter dominates the emission of FSQRs, while in low power sources both components have almost the same importance (although for some TeV sources there are indications that the high-energy component can dominate during flares, e.g. Foschini et al. 2007).

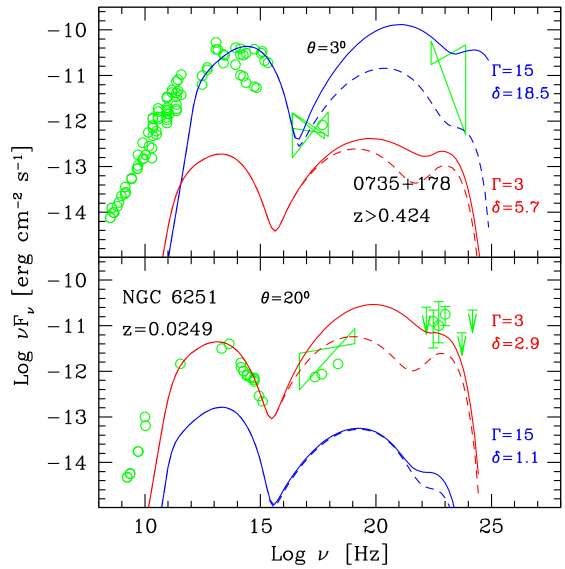

Fig. 1.— *Upper panel:* Spectral Energy Distribution of the BL Lac object 0735+178 (green points), together with the results of the emission model for a structured jet (Ghisellini et al. 2005), comprising the contribution of the fast ($\Gamma = 15$) spine (blue) and the slower ($\Gamma = 3$) layer (red), assuming a small angle of view ($\theta = 3^o$) as typically derived for blazars. The dashed lines report the Inverse Compton emission calculated only taking into account the synchrotron photons produced locally. *Lower panel:* the expected SED from the same jet observed at a larger angle of view ($\theta = 20^o$). In this case the emission is dominated by the layer (red), since the observer lies outside the narrow emission cone of the stronger beamed spine (blue). For comparison, the green points report the SED of the FR I jet in NGC 6251.

It is worth noting that a trend between the peak of the emission and the total luminosity has been derived also for Gamma Ray Burst (Ghirlanda et al. 2004), for which the emission is believed to be produced inside an ultra-relativistic (bulk Lorentz factors $\Gamma = 100 - 10^3$) jet produced during the collapse of massive stars. In this case, however, the two quantities are correlated, the most powerful sources showing the peak at high-energy and *vice-versa*.

2.2 Jet speed, magnetic fields, power and composition

The description of the blazars SED with the synchrotron and IC components allows us to derive with some confidence the values of the basic physical quantities of the jet (e.g., Ghisellini et al. 1998, Tavecchio et al. 2000a, 2001, Kubo et al. 1998, Sikora & Madejski 2001). In particular:

• Bulk Lorentz factors in the interval $\Gamma = 10 - 20$ are commonly derived, consistent with those inferred at pc scale through VLBI studies (e.g., Kellermann et al. 2004). However, larger values (up to $\Gamma \gtrsim 50$) are required by synchro-SSC models of some TeV BL Lac (Krawczynski et al. 2002, Konopelko et al. 2003). These values are in contrast with the small, often subluminal, apparent speeds measured with VLBI in these sources (e.g., Edwards & Piner 2002, Piner & Edwards 2004). A way to explain this discrepancy is to admit that the jet decelerates between the subpc scale and the VLBI scale (Georganopoulos & Kazanas 2003). A *bonus* of this interpretation is that if one takes into account in the calculation of the IC emission the target photons coming from the outer, decelerating, portion of the jet, it is possible to decrease the required Lorentz factor to "standard" values $\Gamma \lesssim 20$. Another possibilities along the same lines is to assume a structured jet, with a fast spine surrounded by a slower layer (Ghisellini et al. 2005). Apart from decrease the required Lorentz factor, the strong radiative coupling between the fast spine and the slow layer offers the possibility to justify the assumed deceleration of the spine as effect of the radiation drag (*Compton drag* effect). The presence of such a structure is also supported by the direct radio imaging of some jets (Giroletti et al. 2004) and is required by the unification of the spectral properties of BL Lac objects and their parent low power (FR I) radiogalaxies (Chiaberge et al. 2000). Ghisellini et al. (2005) also note that the radiative coupling between the spine and the layer can boost the IC emission from both regions, with the consequence that FR I radiogalaxies could be strong $\gamma-$ray emitters. An example is reported in Fig.(1)

• Magnetic fields with intensity ranging from ~ 0.1 G to few G are usually derived. The magnetic field intensity increases with the radiative luminosity of the source, being smaller in the low-power BL Lacs and larger in the powerful FSRQs. In the latter sources the values of the magnetic energy density are consistent with equipartition with the energy density of relativistic electrons, while in BL Lacs, especially the TeV emitting ones, values below equipartition (by one order of magnitude) have been derived (Maraschi et al. 1999, Kino et al. 2002).

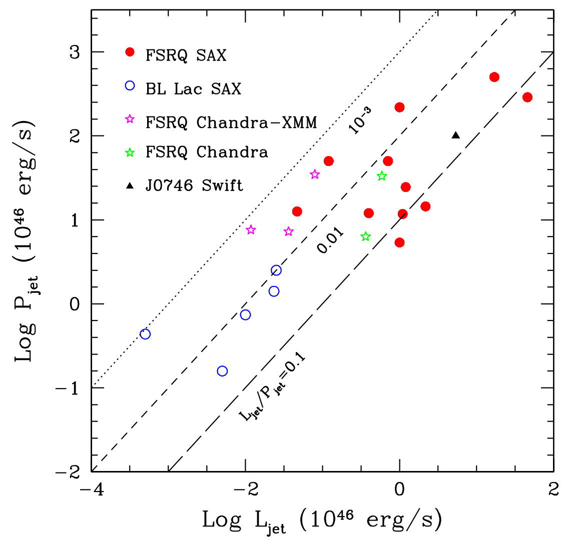

Fig. 2.— The jet power $P_{\rm jet}$ compared with the beaming-corrected radiative luminosity $L_{\rm jet}$ for a group of blazars, including those originally discussed in Maraschi & Tavecchio (2003) plus other studied recently in Sambruna et al. (2006a,b) and Tavecchio et al. (2007). Power is estimated assuming a composition of 1 proton per relativistic electron. The diagonal lines indicate different values of the radiative efficiency ($L_{\rm jet}/P_{\rm jet}$), from 10% to 0.1% (powers on both axis are expressed in units of 10^{46} erg/s).

• The jet power can be inferred from the knowledge of the bulk Lorentz factor and the particle density (e.g. Celotti & Fabian 1993). In this respect a key information is the composition of the jet. Unfortunately, our knowledge of the matter content of jets is still rather poor. The observations only allow us to directly probe the relativistic electrons (and the magnetic field) in the emitting regions, but little is known on the possible existence of cold pairs and protons and on the relative abundance of all the species. However, some constraints on the matter composition can be derived using the condition that the jet carries enough power to emit the radiation that we observe. Using this condition, one can rule out (at least for FSRQs) the possibility that the jet contains only the relativistic electrons that we observe (e.g., Maraschi & Tavecchio 2003, Sikora et al. 2005). Therefore, another component, which carries most of the jet power, is required. A direct possibility is to assume a "normal" plasma, with approximately 1 proton per relativistic electron. In Fig.(2) we report the comparison between the jet power calculated assuming

the e-p composition and the beaming-corrected radiative luminosity inferred for a group of blazars, including the sample of Maraschi & Tavecchio (2003) and other sources recently studied. FSRQs are mainly concentrated in the range of powers $P_{\rm jet} = 10^{47} - 10^{48}$ erg/s, with few objects reaching larger powers, while BL Lac jets have power of the order of $P_{\rm jet} = 10^{45} - 10^{46}$ erg/s. The radiative efficiencies (defined as the ratio $L_{\rm jet}/P_{\rm jet}$) range from at least 0.1% to 10%.

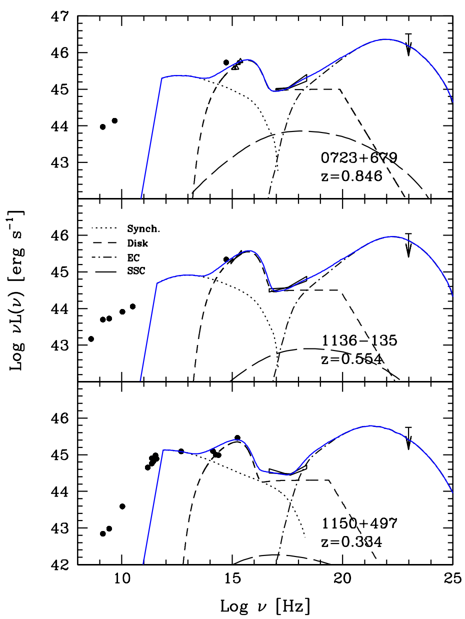

Fig. 3.— Spectral Energy Distributions of the core of three radio-loud quasars with detected X-ray emission from the large scale jet (Sambruna et al. 2006a). The optical-UV data and the X-ray spectrum are well modeled as a mix of disk and jet emission. The lines report the total emission model (solid) and the single components (dotted: synchrotron; long dashed: SSC; short dashed: disk; dotted line: EC).

A possible alternative to protons is a dominant population of cold (i.e. not relativistic) pairs. This possibility could be *directly* tested, since a large amount of cold pairs would produce a characteristic spectral bump in the soft X-ray band, through the "bulk Compton" process between the pairs and the soft ambient photons (Begelman & Sikora 1987, Celotti, Ghisellini & Fabian 2007). Unfortunately, the detection of this spectral feature is difficult, since it can be easily outshined by the IC emission from the relativistic electrons.

A last possibility is that the jet is not matter-dominated, but that the power is supported by dominant magnetic fields (Blandford 2002, Lyutikov 2003). However, there are no strong observational evidences supporting this possibility (Sikora et al. 2005).

2.3 Jet power and accretion power

For the objects reported in Fig.(2) we also have information on the luminosity of the accretion flow, either directly (when the "blue-bump" is visible) or indirectly through the measure of the luminosity of the emission lines. As an example, in Fig.(3) we report the SEDs of three interesting sources recently studied by us (Sambruna et al. 2006a), in which the presence of an important contribution from the disk is clearly described by the shape of the optical-UV continuum and supported by the presence of a weak iron line in the X-ray spectrum, which can thus be interpreted as a mix of the emission from the disk and the relativistic jet.

It is thus possible to compare the power carried away by the relativistic flow with that supplied by the accreting material. Previous studies indicate a correlation between the accretion luminosity and the jet power estimated either through the measure of the energy stored in radio-lobes (Rawlings & Saunders 1991) or the modeling of the emission of the jet at VLBI scales (Celotti, Padovani & Ghisellini 1997). The existence of such relations supports scenarios for jet production requiring a direct link between outflows and accretion (e.g., Blandford & Payne 1982).

The extension of this comparison to the blazar scale offers the possibility of a more direct measure of the power, in regions closer to the central BH. The comparison is reported in Fig.(4). Most of the BL Lac objects do not have reliable measures of line luminosities and only upper limits on the accretion luminosity can be derived. A trend is clearly visible in Fig.(4), with the accretion luminosity increasing with the jet power.

Clearly the jets carries a sizable fraction of the accretion power. As indicated by the dashed line, on average the jet power derived for FSRQs is 10 times the accretion luminosity. For a standard accretion efficiency of 10%, this implies that in these systems, the jets carries a power *of the same order* of the accretion power. For BL Lac sources, apparently the jet carries a power much larger than that associated to accretion flow. However, it is likely that the radiative efficiency of the accretion flow in these low-power AGNs is smaller than that of the standard accretion disk.

2.4 A unifying view

The pieces of evidence collected above can be used to construct a unifying scenario for the properties of the jet at small scales.

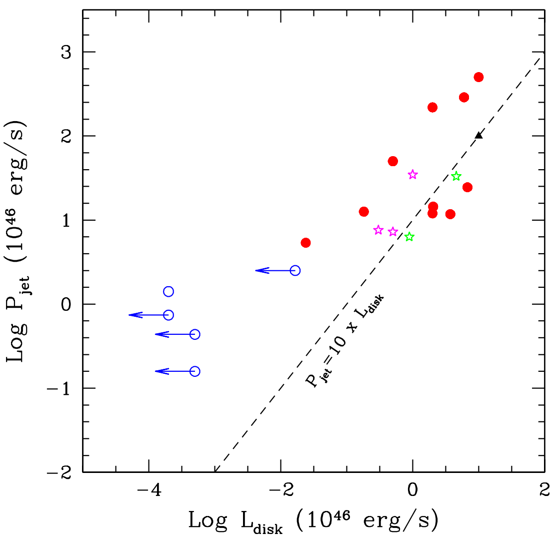

Fig. 4.— Comparison between the jet power and the accretion luminosity, for the same sources reported in Fig.(2). When possible, the accretion luminosity has been directly inferred from the "blue bump" in the optical-UV band, otherwise we used the luminosity of the broad emission lines, assuming a ratio of 0.1 between the luminosity of the Broad Line Region and that of the accretion disk (powers on both axis are expressed in units of 10^{46} erg/s).

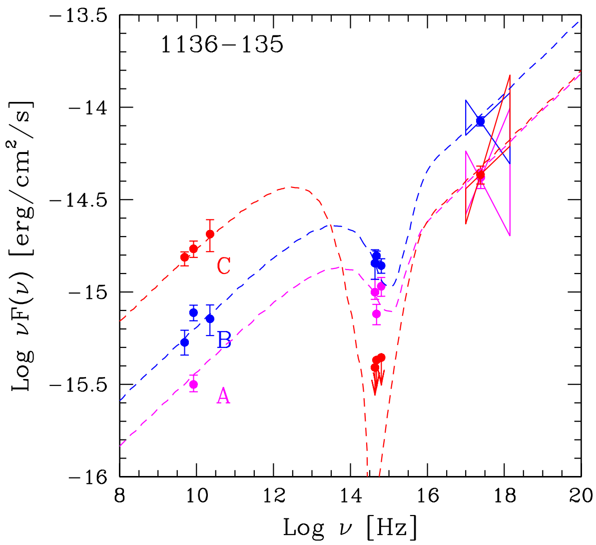

Fig. 5.— SED of three knots of the jet associated to the quasar 1136-135, constructed with radio (VLA), optical (*HST*) and X-ray (*Chandra*) data. The optical data exclude a unique power-law spectrum from radio to X-rays. The lines report the synchrotron and IC/CMB emission which reproduce the data (from Sambruna et al. 2006c).

As pointed out by Ghisellini et al. (1998), the modeling of the SED of a large group of sources suggests that the "blazar sequence" is related to a trend in some of the physical parameters of the jet: the energy of the electrons emitting at the peak of the SEDs systematically increases from high to low power sources while, at the same time, the energy density in the magnetic field and radiation decreases. Ghisellini et al. (1998) argued that this trend can be the result of the balance between the cooling rate (measured by the amount of total energy density) and the (almost universal) acceleration rate of the electrons. The most powerful sources have a large amount of magnetic and radiation energy density, determining a severe cooling and thus a small value for the equilibrium Lorentz factor of the electrons. On the contrary, BL Lacs are characterized by a low level of cooling, explaining the large Lorentz factors of the electrons in these sources.

Along these lines, one can also envisage an evolutionary scenario in which the progressive "cleaning" of the environment of the jet during the cosmological evolution (e.g. Fabian et al. 1999) leads to a decreasing accretion rate, which, in turn, implies a decrease of the power of the jet, as suggested by the results of Sect.2.3. The decreasing density of the AGN environment would also lead to a minor photon density, which, as we discussed below, probably regulates the cooling of the electrons, at least for powerful FSRQ, in which cooling is dominated by the IC process. The net result of this process would be that an initially powerful FSRQ evolves into a low-power, BL Lac object (Boettcher & Dermer 2002, Cavaliere & D'Elia 2002).

Finally it is worth to stress that most of the discussion above is based on modeling of SEDs often comprising non-simultaneous data. In particular, $\gamma-$ray data are usually averages of the positive detections, although it is well known that the high-energy emission is highly variable. *GLAST*, with its good sensitivity and the wide field of view will allows us to better characterize the high-energy component and to derive stronger constraints on the properties of the jet at small scales.

3 Large scale jets in quasars

As discussed elsewhere in these proceedings (Marshall, Schwartz), the detection of dozens of resolved jets in the X-rays, initiated a new active field of research (a recent review is Harris & Krawczynki 2006). While the multifrequency emission of low power (FR I) jets is commonly interpreted as due to a unique (power-law or steepening power-law) synchrotron component from the radio to the X-ray band (e.g., Worrall et al. 2001), more debated is the interpretation of the emission from large power (FR II) jets hosted by quasars. Clearly (see Fig.5), a unique power-law component cannot reproduce the multifrequency data, showing a well defined "valley" in the optical region (Schwartz et al. 2000). The most direct explanation is that, in analogy with blazars, we are observing two emission components from the same electrons, the synchrotron emission accounting for the radio and (in some cases) the optical emission and the IC mechanism producing the bright X-ray component. The extreme power requirements allow us to rule out SSC emission (Schwartz et al. 2000, Tavecchio et al. 2004). An alternative is the IC scattering of photons of the Cosmic Microwave Background. However, in order to reproduce the luminous X-ray emission we have to assume that the CMB photons are boosted in the jet frame, requiring relatively large bulk Lorentz factors of the jet ($\Gamma \gtrsim 2-3$) at these large scales (Tavecchio et al. 2000b, Celotti et al. 2001). If we further require the equipartition between magnetic field and relativistic electrons energy densities, we can completely determine the physical parameters. In this framework the X-ray emission originates from electrons belonging to the low-energy end of the energy distribution (corresponding to Lorentz factors $\gamma \sim 10-20$), whose synchrotron emission, being at very low frequencies, is unaccessible to radio observations

In the following discussion we assume that the IC/CMB model is the correct interpretation of the overall multifrequency emission of knots in large scale jets of quasars. Criticisms and alternatives to this interpretation can be found in Aharonian (2002), Stawarz et al. (2004), Atoyan & Dermer (2004), Kataoka & Stawarz (2005). Recent work specific for the jet of 3C 273 added further problematic elements (Uchiyama et al. 2006, Jester et al. 2006). However, caution should be used in generalizing these results obtained for a single source, that for some aspects is an "outlier", to the entire population of jets in quasars.

3.1 Jet parameters

The application of the IC/CMB model to the observed multifrequency emission of a relatively large number of quasars provide quite interesting constraints on the jet (see e.g., Sambruna et al. 2002, 2004, 2006c, Kataoka & Stawarz 2005, Schwartz et al. 2006):

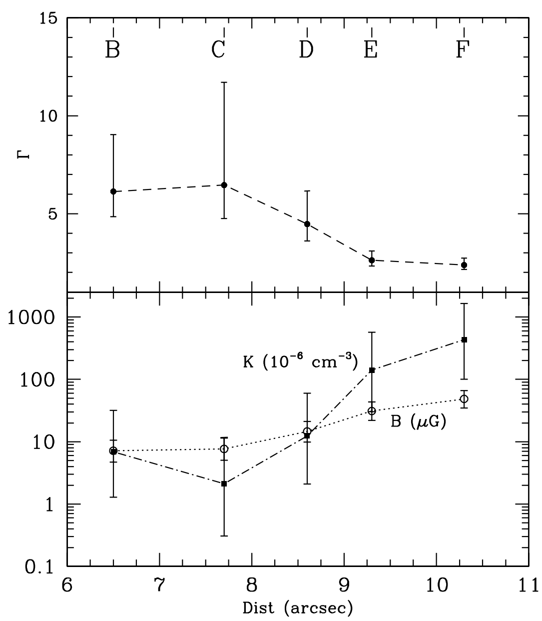

Fig. 6.— Profiles of the Lorentz factor Γ (top panel), magnetic field intensity, B and electron density, K (lower panel) for regions B–F of the jet of PKS 1136-135 estimated from the radiative IC/CMB model (from Tavecchio et al. 2006). The decreasing Lorentz factor marks the deceleration of the jet, accompanied by increasing of both the magnetic field and electron density. The inferred deceleration can be interpreted as due to the loading of the jet by entrainment of external material.

• The Lorentz factors obtained under the assumption of equipartition generally lies in the range $\Gamma = 5-15$. These values are in several cases consistent with those at pc scale, required by the observed superluminal speeds measured with VLBI. However, large Lorentz factors seem to be in contrast with independent estimates based on the jet to counter jet luminosity ratio of a sample of radio-loud quasars, suggesting $\Gamma \lesssim 3$ (Wardle & Aaron 1997). A solution is to admit that the radio emission considered in these estimates originates in a slower layer surrounding the faster jet emitting at X-rays.

In some cases there is a trend for Γ to *decrease* along the jet, indicating the possible deceleration of the flow (Georganopoulos & Kazanas 2004). The best studied case is that of 1136-135 (see Fig.6), for which we discussed the possibility that the deceleration is induced by entrainment of external gas (Tavecchio et al.

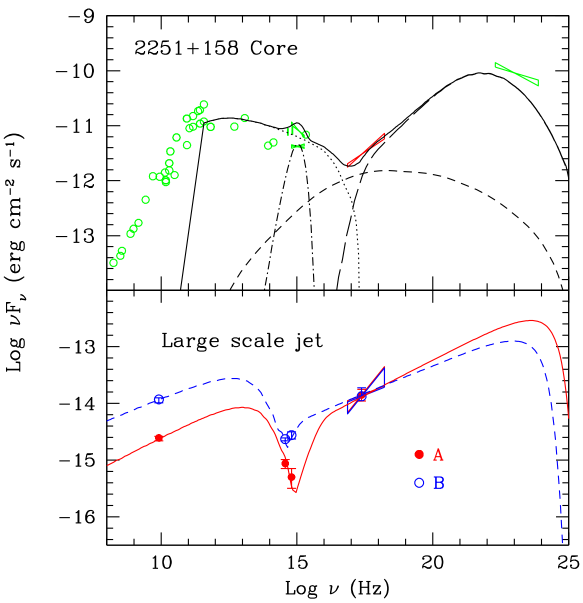

Fig. 7.— Spectral Energy Distributions of different emission regions for the sources 2251+158. *Upper panel*: *Chandra* X-ray spectra of the blazar regions are shown together with non simultaneous multifrequency data. The lines report the emission model used to reproduce the data (solid) with the different components (dotted: synchrotron; short dashed: SSC; long dashed: EC; dotted line: disk.) *Lower panel*: radio, optical (*HST*) and X-ray (*Chandra*) fluxes for different large scale jet knots. The latter show the typical two component structure, well explained by the IC/CMB model. Note that HST data, although mostly non-detections, provide very important limits that prevent a single-component interpretation of the SED.

2006). However, this behaviour is not ubiquitous (e.g., Schwartz, this volume).

• The insensity of the magnetic field estimated assuming equipartition generally lies in the range $B = 10^{-6} - 10^{-5}$ G. If the equipartition condition is relaxed and if the Lorentz factor of the jet is constrained to be $\Gamma \lesssim 5$ as discussed above, the resulting magnetic field is below equipartition, and the plasma is strongy matter dominated (Kataoka & Stawarz 2005). Sub-equipartition fields are also suggested for the low-power jet in M87, based on the current upper limit of its high-energy SSC emission (Stawarz et al. 2005). In general, relaxing the equipartition condition allowing the electrons (the magnetic field) to dominate, implies a lower (larger) bulk Lorentz factor and increases the jet power (see Ghisellini & Celotti 2001, Tavecchio et al. 2004).

In the jets for which there is evidence for deceleration, the inferred magnetic field *increases* along the jet (Fig.6), as expected from the adiabatic compression induced by the deceleration.

• Rather interesting is the fact that the shape of optical and X-ray continuum constrains the lower energy end of the electron energy distribution (corresponding to Lorentz factors in the range $\gamma_{\rm min} = 5 - 20$), a quantity not easily accessible to the direct measure with radio observations. The direct estimate of $\gamma_{\rm min}$ allows us to robustly constrain the number of relativistic electrons, particularly important in view of the determination of the jet power.

• The derived jet power (assuming the e-p composition) are often rather large, in the range $P_{\rm jet} = 10^{47} - 10^{48}$ erg/s (see also Ghisellini & Celotti 2001). The large energetic requirement is sometimes considered a problem for the IC/CMB interpretation (e.g., Atoyan & Dermer 2004). However, all the sources for which the IC/CMB model has been applied are powerful quasars and, moreover, these values are consistent with the power derived for blazars of comparable radio power (Fig.2; see also below).

4 Jets from small to large scales

Coupling information derived at subparsec scale and kiloparsec scale for the same jet could have great potential to help in constructing a global understanding of powerful extragalactic jets. This approach can be fruitfully applied to those blazars showing a large-scale jet long enough to be resolved by *Chandra*. Unfortunately, only few jets can be studied on both scales, since the best studied blazars do not tend to have well studied large-scale jets, precisely because the former are the most closely aligned with the line of sight, reducing the projected angular dimension of the large scale jet.

We first investigated (Tavecchio et al. 2004) two well known blazars serendipitously belonging to the sample surveyed with *Chandra* by Sambruna et al. (2004) and the study has been recently extended to other 4 sources (Tavecchio et al. 2007). Similar results are reported in Jorstad & Marscher (2004, 2006). As an example we report in Fig.(7) the SEDs of the blazar region and two knots of the resolved jet of the quasar 2251+158, with the emission models used to reproduce the data (from Tavecchio et al. 2007).

From the independent modeling of the SED of the blazar and large scale region we derived the basic parameters of the flow at the two scales for the six sources. The comparison between Lorentz factors and powers determined for the the blazar core (*inner*) and the large

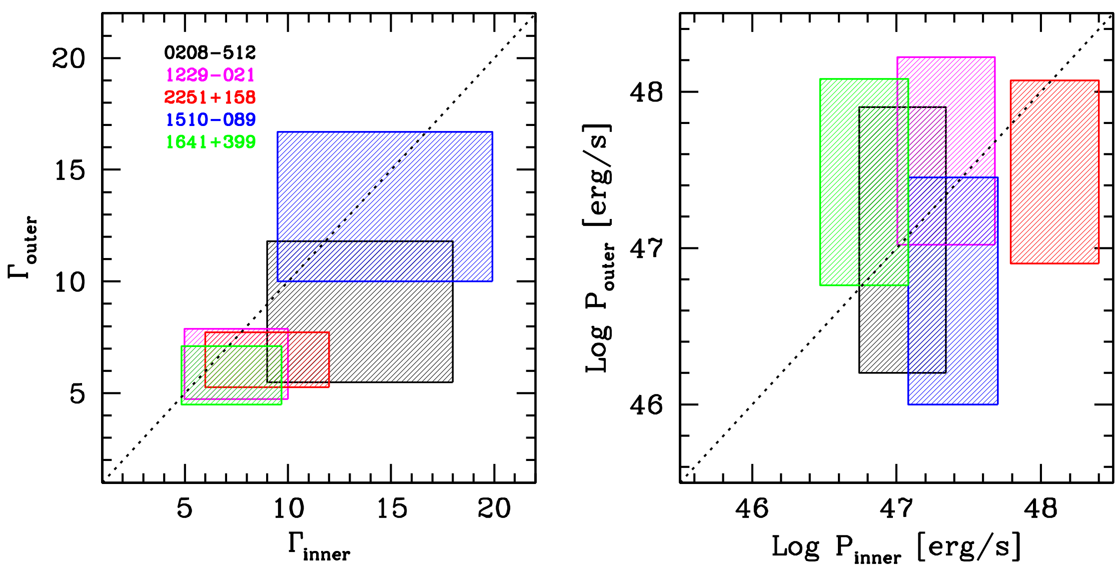

Fig. 8.— Comparison between the jet Lorentz factor (*left panel*) and the jet power (*right panel*) evaluated independently for the inner (blazar) jet and the kpc-scale jet for all sources for which sufficient data exist. The rectangles include uncertainties due to observational errors and to assumptions about the viewing angle, as explained in the text. The bulk Lorentz factor is consistent with being constant from the subpc to the large scale scale jet and in any case is still highly relativistic on the largest scale; the jet power is also consistent with being constant up to very large scales, although the uncertainties on the large scale estimates are rather large.

jet knots (*outer*) is reported in Fig.(8), in which the rectangles include the region of the plane allowed by the uncertainty on the data and in the modeling. The plots show that, on average, the Lorentz factor and the power derived at the two scales are in agreement, suggesting that jets do not suffer important deceleration and energy losses from the regions close to the black hole to hundreds of kpc scale. However, the large uncertainty, affecting in particular the derived power (in particular the values of $P_{\rm outer}$, spanning in some cases a range larger than a decade), prevent to draw a stronger conclusion.

5 Conclusions: a simple view

Our understanding of the physics associated to relativistic jets is rapidly growing. Blazars allow us to investigate the innermost regions of the jet, not far from the region where the flow is accelerated and collimated (e.g., Junor et al. 1999). The modeling of the emission observed from blazars provides important, albeit not conclusive, clues on speed, power and composition of the flow and on the relationship with the accretion feeding the central BH. On the other extreme of spatial scales, multifrequency observations of large scale jets are starting to shed some light on some of the basic problems.

The possibility to use the information collected at both scale can be helpful in addressing some of the fundamental issues concerning jet. Indeed, the results of the last section indicate that jets of powerful quasars seem to evolve almost unperturbed from small to large scales. However, as previously discussed, in some cases there is complementary evidence suggesting that before its termination the jet suffers important deceleration, marked by a decreasing Doppler factor and the increase of magnetic field intensity and particle density (Georganopoulos & Kazanas 2004, Sambruna et al. 2006c). The deceleration can be plausibly induced by entrainment of external gas (Tavecchio et al. 2006), whose effects become important only when the cumulative amount of entrained gas reaches some appreciable level (Bicknell 1994). Moreover, the mixing layer thought to permit the entrainment of the gas into the jet is believed to grow along the jet. Therefore, entrainment can coexist with the evidence of the conservation of power and speed, since the deceleration is expected to become important only after some distance along the jet.

All these elements can be used to depict a simple scenario, in which very powerful jets evolve freely, almost unperturbed, up to large (∼100 kpc) scale, conserving the original power and speed (e.g., Blandford & Königl 1979). In some cases (depending on external conditions and jet power), the entrained mass becomes dynamically important before the jet end, leading to the inferred deceleration (e.g. the case of 1136-135, Tavecchio et al. 2006). It is tempting to extend this view to include low-power FR I sources, characterized by a small mass flux and therefore naturally more prone to deceleration.

Although model dependent, these result are quite interesting, and it would be extremely important to confirm and strengthen them with an enlarged sample of blazars with multifrequency observations of the large scale jet. *GLAST* (scheduled to be launched at the end of 2007) is expected to greatly enlarge the number of known γ-ray radio-loud AGNs. Likely, most of the sources associated to large scale jets with known X-ray emission will be detected in the γ-ray band, allowing to better characterize the SED of the core and therefore increasing the number of objects suitable for this study.

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